Extended Abstract

Assessment of the impact of COVID-19 in waste collection services: the case of Cascais Environment

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1. Introduction

The concern with Waste Management dates to the 1972 Paris Summit, when the Member States of the European Union began to become aware of the need for policies that were based on the environment, especially its preservation for future generations. Waste management includes an inherent value chain among itself. It is understood "as the set of technical, administrative and financial activities necessary for the disposal, collection, transport, treatment, recovery and disposal of waste, including the planning and supervision of such operations, as well as the monitoring of the final destination sites, after their closure" (Presidência do Conselho de Ministros, 2015).

In Portugal, the Decree-law No. 194/2009 of August 20th has regulated the types of models that can be adopted for the waste management systems. These management models allow the participation of the private sector at various levels, including the delegation or total concession of the service. This legal framework also established the minimum quality levels that the services have to comply.

The Water and Waste Services Regulator Entity (ERSAR) is defined as the entity responsible for regulating the different tariffs applied in the waste management systems, promoting the protection of user interests, safeguarding the economic viability and sustainability of the service in the medium and long term, as well as supervising the quality of the service provided (ERSAR, 2020).

In order to make comparisons between different management entities, geographically separated, ERSAR has created a set of indicators, where the benchmarking methodology is applied, producing an annual report that summarizes and compares all the values registered by this entity. This method is now one of the tools provided under Total Quality Management (TQM) to achieve performance targets from the best practices and its processes (Anand & Kodali, 2008).

In the municipality of Cascais, the Municipal Environment Company of Cascais (EMAC) began its activity in 2005, to meet both urban cleaning and waste collection needs.

Cascais Ambiente is responsible for the following services: collection and transport of Urban Solid Waste (RSU); Selective Collection of Urban Waste (SEL); collection and transport of discarded large objects (RMO); collection and transport of garden waste (RCJ).

However, in the year 2020 there were mandatory containment measures that may have led to a change in the behavior and pattern of the population with a direct impact on the waste sector.

This dissertation aims to analyze the impacts that the mandatory confinement, due to SARS-Cov-2, had on the waste collection service, proposing a methodology based on Descriptive Statistics, which allows, from data collected by the Cascais Council's Management Entity, to assess whether there were global changes in certain variables. The analysis also allows for the same variables to perceive, through the formulation of adimensional Indices, if there is a change of pattern in the general behavior of the population, being these insensitive to external factors.

2. Case of study

2.1. Contextualization and framing of the municipality

The Municipality of Cascais covers an area of approximately 97 Km2. Due to the administrative reform in 2013, it is now composed of four parishes instead of the six previously existing: Alcabideche, Carcavelos and Parede, Cascais and Estoril and São Domingos de Rana (Figure 1).

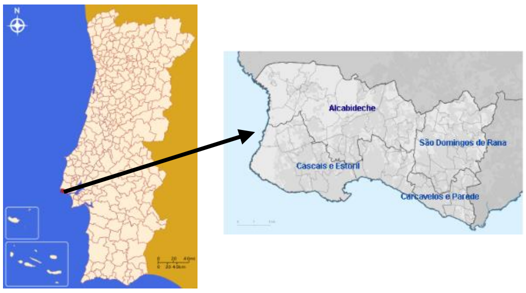

Figure 1 - Geographic Position and Administrative Division of the Municipality of Cascais

According to PORDATA and through data made available by the National Institute of Statistics (INE), which were updated on June 15, 2020, it is possible to obtain the evolution of the Resident Population in the Municipality of Cascais between 2001 and 2019 (Figure 2).

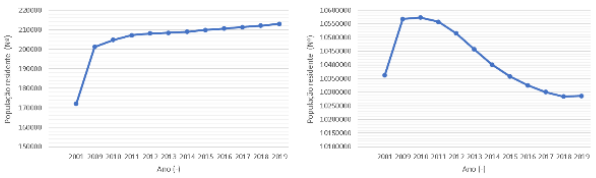

Figure 2 - Evolution of the Resident Population in Cascais (left) and Portugal (right) (PORDATA, INE - Annual Estimates of Resident Population)

It can be observed that there has been an increase in the resident population of the municipality in contrast to the decrease in the resident population in Portugal (mainland and its archipelagos). This population increase, which is around 24%, can be explained from the data presented by Cascais Data and provided by the Foreigners and Border Service (SEF), which show a significant increase in the number of foreign residents in the municipality.

In geographical terms, Cascais is delimited to the North by the Sintra Mountains, to the South and West by the Atlantic Ocean and to the East by the Oeiras municipality. These delimitations confer characteristics that impose certain challenges and constraints on the way waste collection is managed. Although Cascais is mostly urban territory, its delimitation to the North with the Sintra Mountains gives it rural characteristics, changing the construction typology and the distance between housing units.

This heterogeneity in the spatial distribution of the population mirrors itself, with the highest population densities being concentrated in the south and east of the municipality.

2.2. Characterization of the waste management service

Cascais Ambiente is responsible for providing the following services:

- collection and transport of Urban Solid Waste (RSU);
- selective collection of Urban Waste (SEL);
- collection and transportation of Disposable Large Objects (RMO);
- collection and transportation of garden waste (RCJ).

Only the RSU and SEL services will be treated in the scope of this study. If the RSU constitutes a single waste stream, the SELs are subdivided into 4 segregated streams: i) paper and cardboard; ii) plastic and metal; iii) glass; and iv) biodegradable urban waste (RUB). Thus, in practice the study comprises the analysis of the performance of 5 waste streams.

The waste collection service in general, and the RSU and SEL in particular, is carried out by dividing the Municipality of Cascais into collection circuits. The definition of the circuits seeks to balance the density of containers and the amount of waste produced with the time needed for its collection, limiting the time spent to a constraint of 6 working hours. Thus, each circuit is determined by the time that a collection truck, regardless of the waste flow involved, takes to collect the waste in each route, that connects the existing containers in the municipality. The circuit includes the duration of the journey from the exit of the truck from the yard to the collection of all containers and its disposal in Tratolixo and getting back to base again.

Since the act of collection is fast, the RSU routes are designed so that there is a relatively constant proximity between each collection station, thus enabling the possibility of increasing both efficiency and effectiveness of employees.

When it comes to the collection of SEL, more specifically the paper, plastic and glass flows, the collection vehicles allocated to the service require crane installation in order to lift the containers. SEL containers are usually larger than RSU containers and have a distinct operation, which requires the transfer of waste from the top of the vehicles instead of the rear.

In addition to the differences in terms of the equipment allocated to each waste stream, the production rates of each stream are different. The higher production of RSU requires shorter and more frequent circuits than, for the different SEL streams.

Given the complexity of the activity developed by Cascais Ambiente, the management of waste collection services is assisted by an information system that interconnects the vehicles with the headquarters and allows the collection, access and analysis of data at the level of each route performed in each circuit. Among other aspects, the available data includes: i) the duration; ii) the distance traveled; iii) the number of stops; iv) the number of discharges at the Tratolixo; v) the amount of waste collected; and vi) the constitution of the team that carried out the journey.

3. Methodology

3.1. Framing

The analysis of the impact of COVID-19 on waste generation and, consequently, on the waste management service of the Municipality of Cascais is based on a statistical analysis. This involved, in a first stage, the collection of information and the preparation of a database that would allow the comparison of the operation of the collection service in the context of a pandemic or not. Then, the existence of statistically significant differences in the data of the waste collection service in both contexts is assessed, controlling possible effects of seasonality and intra-annual differences.

3.2. Obtaining the Data Base

3.2.1. Collecting and cleaning the Data

The data can be obtained from the information systems of the management entities, which must contain an individual record of the duration, quantity transported, distance travelled, discharges at the waste management entity on high and the number of stops of each waste collection shift per flow and circuit.

Despite the level of sophistication and automation of the implemented systems, in general there are still errors in the records of various origins (e.g. communication failures, power failures, system limitations). To eliminate them, data quality control was carried out.

When these repairs are completed, we will have to make sure that the final database contains a sufficiently large set of data to be able to analyze them.

3.2.2. Index Calculation

In addition to possible trends in generation of waste on an annual scale, the existence of seasonality on both a monthly and weekly scale may make it impossible to compare or identify patterns between distinct moments in time (distinct weeks, months or years). For example, the identification of possible seasonality patterns over the various months of the year can be masked by looking at years when the total amount of waste collected is very different (e.g.

due to population growth). The pattern may be present, possibly even visible graphically, but it is impossible to test statistically for divergence in magnitude.

To overcome this obstacle, values have been normalized, namely by calculating indexes: i) annual; ii) monthly; and iii) weekly. The indexes are calculated by dividing the recorded values by the average value of the respective time scale. Thus, on a monthly scale, the values are divided by the average value of the corresponding year and on a weekly scale, by the average value of the corresponding month. The values determined in this way are adimensional and measure the variability in relation to the average pattern of the year, month or week. This transformation allows, for example, the comparison of weekdays of weeks, months or years, to identify possible patterns by removing the influence of global trends in the medium and long term.

3.3. Data Base analysis

3.3.1. Normality testing

In order to apply several statistical tests, one of the prerequisites is to check the normality distribution in the sample to be tested, i.e. to check whether the probability distribution of a given data set can be approximated by the normal distribution. The normality of the data sample can be measured using a graphical or a numerical method.

In order to avoid subjectivity in graphical interpretation, numerical methods were favored in this study, with two of the numerical methods being adopted, the most frequently used in practice, the Kolmogorov-Smirnov and Shapiro-Wilk tests and adopting a significance level of 5% to assess the normality or otherwise of the data.

3.3.2. Outliers testing

Despite the preliminary cleaning of the database to exclude data that clearly constitute registration errors, there may still exist outliers: cases whose value is significantly lower or higher when compared to the overall data set.

These variances of certain values within a given data group are often due to incorrect measurements of the data or to erratic input into the database system. If it turns out that both of the above propositions do not occur, then they are no longer called outliers but rare events.

Having said that, one of the objectives of outlier detection is the identification of data that can influence/enable assumptions of a given statistical test, for example: outliers that run away from a normal distribution, a necessary assumption for the application of the ANOVA test, thus becoming an essential step before any statistical analysis for this type of testing.

There are 2 types of methods that can be used to detect outliers: formal tests and informal tests. For the present document we will only take into consideration the informal tests that in their operation, generate a range of values whose marking serves as a criterion for the possibility of a certain value being an outlier.

Tukey's method is an informal test and is the most graphic method that allows us to visualize continuous data information such as: the median, 1st quartile, 3rd quartile, and minimum and maximum extremes. This method is less sensitive to the existence of extremes in the values of a data set, since it is based on the quantiles of the data distribution instead of the standard deviation and its mean.

The Tukey method, unlike other types of methods, has the particularity that it can be applied to data distributions that do not follow a symmetrical distribution, since it does not start from any assumption for the data distribution.

3.3.3. Descriptive statistics and group comparison

Descriptive statistics is an independent branch within the statistics itself because, unlike the others, it allows the organization and categorization of the data obtained.

Descriptive statistics make use of two types of data: measures of central tendency, where the median, mean and mode are inserted and measures of variability where the standard deviation, variance, asymmetry and kurtosis are inserted.

The two tests that will be considered in this methodology are: the One-Way ANOVA and the Kruskal-Wallis H test. The reason for using these two tests is simply that they are the most widely used by the scientific community and are the most suitable for data with normal or non-normal distributions, respectively.

Statistically significant differences between the distribution of various groups of data can be tested by ANOVA (Unidirectional Covariance Analysis) if the data is normally distributed, or by Kruskal-Wallis test if the data is not normally distributed. In case there are only two categories in comparison, the tests used are t-test (alternative to ANOVA) and Mann-Whitney test (alternative to Kruskal-Wallis test).

The ANOVA test fundamentally allows us to assess whether the sample differences reported are due to real causes (significant differences in the data) or casual causes (dispersion of sample variability). That said, we assume that chance only produces small sample deviations, while large deviations are caused by real causes.

The Kruskal-Wallis test follows the same principles as the ANOVA test but, in order to interpret its results it is necessary to determine whether the distribution that has each group of data has the same variability, because if the variability is the same, a Kruskal Wallis H test should be performed to compare the medians otherwise the same test should be performed, but in this case to compare the means.

However, the ANOVA test and the Kruskal-Wallis test, although giving us back information on the existence of statistically significant differences, are not explicit among which group of variables this difference occurs. Post-hoc tests are necessary to check which groups of variables are affected by these differences. There are several Post-hoc's that can be chosen, however, the most usual is the Tukey test if we assume homogeneity of variance, otherwise we will use the Games-Howell test.

3.3.4. Sensibility Analysis

After performing the tests for each of the variables that we want to deepen and know, if there are statistically relevant differences, it is necessary to know how to look at the information given to us and interpret it. If this type of reflection is not carried out, the tests would be nothing more than numbers obtained through statistical analysis and would not produce a conclusion or a correct assessment of the study that is being carried out. It is from the correlation that can be considered plausible together with the test results that conclusions can be drawn, or the validity and integrity of the proposed analysis can be gauged.

4. Results and discussion

4.1. Data Base analysis

The database for this study was obtained through Cascais Ambiente waste collection management platform MOBA which records, as previously identified, various aspects inherent to waste management activity. Among these, those that were identified as necessary resources for the analysis presented.

After collecting these resources, it was necessary to consider a subdivision, which would provide a basis for logical comparison between them. A subdivision was then devised through time intervals that allowed these values to be compared in a four-month window between two different years. This typology makes it possible to restrict the time interval of analysis to the months when, due to SARS-COV2, containment measures were taken.

After an initial analysis of the information obtained, in order to eliminate possible data entry errors or failures in the data collection equipment a first iteration was carried out (Table 1).

Table 1 - Example of data after restrictions

Year	Month	Day	Weekday	Circuit	Flow	Duration	Lenght (m)	Quantity (Kg)	Consumption(L)
2019	3	1	5	ind_100	I	05:54:05	76 524	13 860	74,5
2019	3	2	6	ind_100	I		33 949	13 720	31,2
2019	3	3	7	ind_100	I			12 320	
2019	3	4	1	ind_100	I		41 404	6 480	38,3

4.2. Calculated Indexes

After processing the entire database, it is necessary to postulate what type of analysis and the level of incidence to be performed.

The data obtained corresponds to an overall quantity whether we analyze the amount of waste produced, the time to carry out a circuit or the distance and the associated consumption and, therefore, the sensitivity of the analysis to be carried out may not be as intrusive and effective as that intended.

In order not to lose this sensitivity and to consider factors such as seasonality, population variations or other types such as the effect of SARS-COV 2, the overall analysis values indicated have been sized by obtaining the following indices:

1st Index:

$$\frac{Quantity}{Average\ joint\ quantity\ of\ the\ years}$$

2nd Index:

$$\frac{Quantity}{Annual\ average\ quantity}$$

3rd Index:

$$\frac{Time}{Annual\ average\ time}$$

4th Index:

$$\frac{\frac{Distance}{Time}}{\frac{Annual\ average\ distance}{Annual\ average\ time}}$$

4.3. Data Base analysis

4.3.1. Amount of waste collected

The organizational chart (Figure 3) illustrates one of the steps within this variable, which has been analyzed.

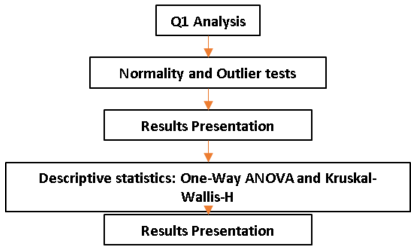

Figure 3 - Organization chart of the analysis carried out for the amount of waste collected

4.3.1.1. Q1 Analysis

The Q1 Analysis compares each waste stream based on the amount of waste collected between the two years: 2019 and 2020. After carrying out the normality tests, it is possible to assess that for the years 2019 and 2020 none of the streams show a normal distribution of data.

Table 2 is an example of normality test results for the flow of general waste.

Table 2 - Example of a table with the results of the normality tests

Normality test

		Kolmogorov-Smirnov[b]			Shapiro-Wilk		
	Year	Statistics	gl	Sig.	Statistics	gl	Sig.
Quantity	2019	,101	2308	,000	,935	2308	,000
	2020	,072	2192	,000	,948	2192	,000

a. Flow = I

When performing these tests, using the Tukey method we verify the existence of values that exceed the interquartile range, in generic terms this range allows us to visualize a greater or lesser dispersion of the values under analysis. The greater the amplitude, the greater the variation of the data. The values outside this range are the so-called outliers, depicted above. However, for this analysis, these values cannot be disregarded, or eliminated because, as this set of data comes from different circuits, with more or less collection points, there are circuits that will always have more, and less waste produced.

As explained previously, since there are only two independent variables: the year 2019 and 2020, the One-Way ANOVA test becomes simply a t-test and the Kruskal-Wallis H test becomes a Mann-Whitney U-test.

The flows that showed a statistically significant difference for a significance of five percent were general waste and biowaste for both tests. If we consider a significance of ten per cent then, in addition to these, the Plastic and Glass flows are also significant.

Since both tests compare the averages, we can analyze in the Figure 4, which translates the averages for each of the flows, with trend lines to analyze if these go against what was found in the tests.

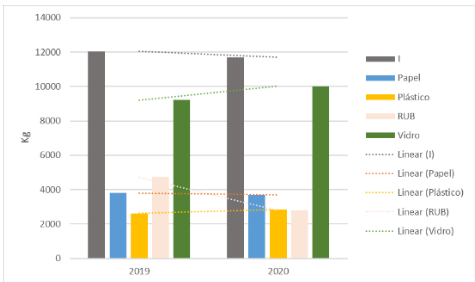

Figure 4 - Comparison of average amount of waste per stream between years

From the visual analysis we could see that these four flows could be expected to produce such results.

4.3.2. Average velocity

The organizational chart (Figure 5) illustrates one of the steps within this variable, which has been analyzed.

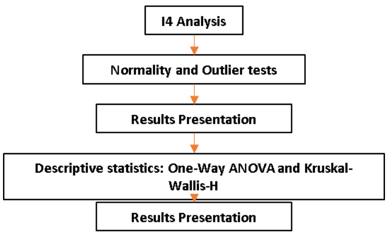

Figure 5 - Organization chart of the analysis carried out for the average velocity

4.3.2.1. I4 analysis

In order to understand if there are statistically significant differences between the two years, the I4 Analysis is based on the 4th index. Its purpose is the analysis of the intra-annual average collection of speed patterns between those of the same flow per circuit,

After applying the Kolmogorov-Smirnov test, we were able to understand which circuits have a normal data distribution (Table 3).

Table 3 - Result of normality tests per month for average collection speed

Normally distributed (%)								
	March		April		May		June	
Flow	2019	2020	2019	2020	2019	2020	2019	2020
Undifferentiated	35	30	60	30	65	55	60	55
Paper	78	100	100	78	78	100	67	89
Plastic	70	90	60	90	100	70	90	70
RUB	100	100	0	50	100	50	100	100
Glass	100	100	100	100	100	100	100	100

Most of the intra-annual combinations for the same circuit include at least a non-standard data distribution as such, the result obtained for the statistical tests is based on Kruskal-Wallis-H, if both are normally distributed it should be interpreted from One-Way ANOVA.

In the month of March:

- 55 % of the circuits have statistically significant differences in the general waste flow;
- 11 % of the circuits have statistically significant differences in the paper waste flow;
- 10 % of the circuits have statistically significant differences in the flow of plastic waste;
- 50 % of the circuits have statistically significant differences in the flow of biowaste;
- Glass waste flow does not show statistically significant differences.

In the month of April:

- 55 % of the circuits have statistically significant differences in the general waste flow;
- 33 % of the circuits have statistically significant differences in the paper waste flow;
- 10 % of the circuits have statistically significant differences in the flow of plastic waste;
- no statistically significant differences in the flow of biowaste and glass are presented.

In the month of May:

- 60 % of the circuits have statistically significant differences in the general waste flow;
- 22 % of the circuits have statistically significant differences in the paper waste flow;

- 20 % of the circuits have statistically significant differences in the flow for plastic waste;
- 50 % of the circuits show statistically significant differences in the flow of biowaste;
- glass waste flow does not show statistically significant differences.

In the month of June:

- 45 % of the circuits have statistically significant differences in the general waste flow;
- 22 % of the circuits have statistically significant differences in the paper waste flow;
- 20 % of the circuits have statistically significant differences in the flow for plastic waste;
- 50 % of the circuits show statistically significant differences in the flow of biowaste;
- glass waste flow does not show statistically significant differences.

From these results and from this analysis, we can see that in all flows the circuits that show statistically significant differences are practically the same in all months, which indicates not only a change in the intra-annual pattern as recorded, but that it spreads over the period under analysis. However, if we compare the patterns between months in the same year it can be seen that the relative pattern of average collection (?) speed changes more over the time span in 2020 than it did in 2019 which shows not only an intra-annual change, but also a non-continuity in the year 2020 pattern that was in 2019.

4.3.3. Waste collection time Analysis

The organizational chart (Figure 6) illustrates one of the steps within this variable, which has been analyzed.

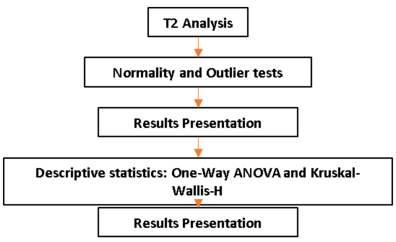

Figure 6 - Organization chart of the analysis carried out for the waste collection time analysis

4.3.3.1. T2 Analysis

In order to be able to deepen which circuits have contributed to this difference in the T1 Analysis, it is necessary to proceed to the T2 Analysis which aims to know, from the waste flows and the circuit, which ones have contributed to this result. The T2 analysis presents:

- 40% of general waste flow circuits with a normal distribution in the year 2019, a rate which falls to zero in the year 2020;
- Paper waste flow shows 66% of the circuits with a normal data distribution while in 2020 this rate rises to 88%;
- plastic waste flow has a normality rate of 80% in 2019 circuits while in 2020 100% of circuits have a normal distribution;
- biowaste flow has 100% of circuits with a normal distribution in 2019 and 2020;
- glass waste flow already maintains the 50% share of circuits with a standard distribution.

As in T1 Analysis, since there is a sufficiently large data set, according to the central limit theorem, the sample mean is close to a normal distribution and therefore statistical tests by Kruskal-Wallis and One-Way ANOVA should theoretically produce the same results.

From the analysis of the results of the statistical tests we conclude that 85% of the general waste flow circuits contribute to a statistically significant difference each year. In the case of Paper waste flow there are only two circuits where this circumstance occurs. For the plastic flow only 40% of the circuits contribute to a difference in the T1 analysis, which means that the variations that existed in these circuits were so significant that they can impact the annual average of waste generation for this flow. In the case of the biowaste flow 50% of the circuits contribute to the difference the same is true for the Glass flow.

We also found that on average in 2020, all flows are distributed between circuits with closer values rather than, as in 2019, there is a discrepancy in waste collection time for different circuits.

5. Conclusion

The main objective of this paper was to carry out a study to draw conclusions about the impacts of mandatory containment, caused by the global SARS-COV2 pandemic, on the waste collection activity, particularly in the Cascais Council.

To this end, it was necessary to carry out a general framework of the evolution of this sector, from its beginnings to the present day and the way it is governed in Portugal.

The proposed methodology to be used in the analysis of the data, based on Descriptive Statistics, proved to be effective in obtaining the answers to the questions that were intended to be further developed from this study.

The application of this methodology required further work in order to eliminate some data that had certain gaps, that were not compatible with the generality observed, in order to avoid erroneous postulation of conclusions, due to errors, that could have propagated and skewed the intended study.

After the application of this methodology we can see that, in general, the waste flows at annual, monthly or circuit level, except for biowaste or Glass waste, do not present a normal distribution of the data.

The outliers that were initially identified in the annual analysis, in reality, are nothing more than circuit values that present a geographical or demographic configuration, different from the generality. This difference confers characteristics in i) waste production, ii) collection time, iii) average collection speed of the circuit, which appear mirrored as data outside the general pattern, but which cannot be disregarded or removed for statistical tests.

After performing and evaluating the statistical tests, we can conclude that, on an annual basis, the average amount of waste generated increased in the case of the Glass waste flow (which indicates greater domestic consumption) and decreased for the biowaste (closed hotels and restaurants) and the general waste (very much due to the fact that the installed capacity was not sufficient for the needs, which led to undue deposition and contamination of the selective flows), with Plastic and Paper waste remaining constant. The pattern of waste generation in general has changed for all waste flows. This change in pattern was also recorded on an annual basis for the time of waste collection.

In the case of the average annual waste collection time it was found that for all flows there was a decrease for this variable.

At a monthly level, both the average amount of waste produced and the average waste collection time are the same as for the annual analysis and, in terms of pattern, there is an intra-annual change for all months, but in inter-monthly terms for both 2019 and 2020 this remains (?) the same. It can also be noted that for the average collection speed the pattern in 2020 is more regular than in 2019.

In short, this study shows that, due to the pandemic and the imposed curfew in the municipality of Cascais, there has been a global change not only in the amount of waste generated, in the time of waste collection, but also a change of pattern, including in average collection speed, in all these variables.

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